

Pathway of Sensory Impulses to Subcortical levels

1. Dorsal Spino Cerebellar t. (post)

Origin: Clark's N [C₈-L₂] on same side

It receives proprioceptⁿ from large cells in the spinal ganglia
(so it is the 2nd order N in the pathway)

Course In Sp. cord in lat. column of white matter of upper lumbar thoracic & cervical segments + Closed medulla

Termination enter the cerebellum through the Inf. cerebellar peduncle

Functions- carry proprioception from trunk & lower limb to cerebellum
Coordinate limb ms. & maintain posture

2. Vent. Spino-cerebellar t. (ant)

- Cells in Post. horn of grey matter in lumbosacral region [V-VII] on same & opposite sides.
- Receive proprioception from large cells in spinal ganglia. (2nd Order N.)
- In sp. cord in lat. column of the white matter at all levels + brain stem

- enter the cerebellum through the Sup. cerebellar peduncle

- Carry proprioception from lower limb to cerebellum.
- Coordinate " movement & maintain posture

3. Spino-Olivary t.

Origin: post. horn cells (laminae IV & V) of the opposite side. Receive proprioceptⁿ from large cells of spinal ganglia.

Course: ascends in the sp. cord.
(all levels)

Termination. Inf. olivary N in medulla.
It sends olivocerebellar fibres to cerebellum through ICP.

Function: carry proprioception to the cerebellum.

4. Spino-tectal t.

- P. HCs. (laminae IV & V) of the opposite side. Receive impulses from spinal ganglia.

- ascends in the sp. cord
(all levels) + brain stem.

- Sup. colliculus of midbrain.

- carry sensory impulses to the tectum (drives spino-visual reflex movement of eye & head towards source of stimulation).

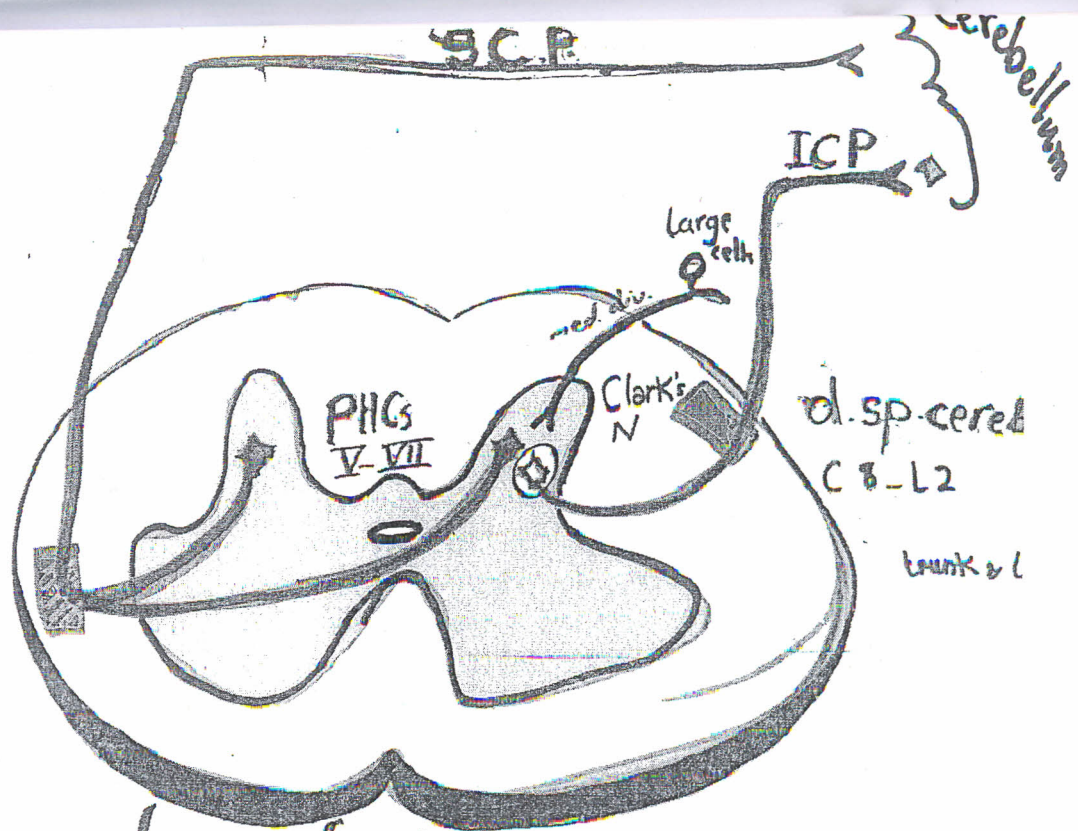
N.B: Unconscious proprioceptive pathway from the upper 1/2 of body [No Clark's N. above C₈]

1st Order N: cells of sp. ganglia.

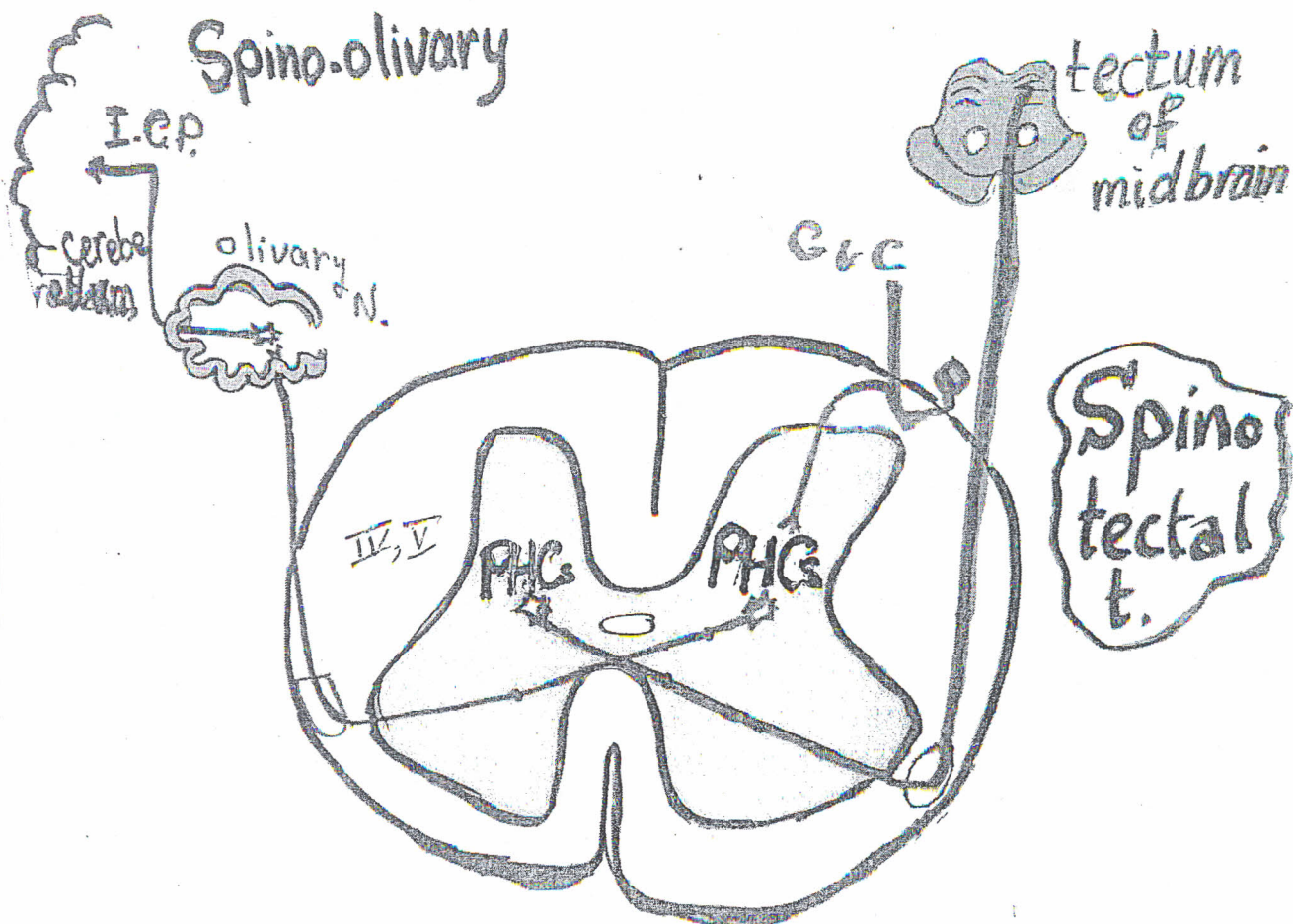
2nd " " : Accessory Cuneate N. (in medulla) ICP → cerebellum (same side).

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Dorsal & Vent sp. cerebellar t



def. tracts that start & end in the sp. cord.

1. Fasciculi proprii :

= axons of associative neurons bet. PHCs & AHCs

- Ascend or descend 1 or 2 segments outside the grey matter (like ring)
- enter the grey matter to end around cells of other segments.

F.: Coordinate function of different segments of sp. cord.

In the fetus, they are the 1st to be myelinated to coordinate its early movements.

2. Lissauer's tract :

def. short tract at the tips of post. horn of all segments.

Origin: small cells of the spinal ganglia. Their axons enter the sp. cord through the lat. division of post. root then ascend or descend 1 or 2 segments to end on: Cells of SGR [Substantia Gelatinosa of Rolandi.

Function: carry pain & temp. from same side of the body.

3. Septomarginal tract

Site post. column of white matter in thoracic, lumbar & sacral segments

= Short descending fibres from Gracile tract.

end on : AHCs

Function : Completes stretch reflex arc.

4. Comma shaped tract

Site: Post. column of white matter in Cervical & upper thoracic segments.

= Short descending fibres from Cuneate tract.

end on AHCs.

Function : Completes stretch reflex arc.

Pyramidal tract

1. Cortico-spinal tracts:

- Fibres arise from cerebral cortex & terminate on AHCs of the sp. cord.
- Origin: Betz cells & other cells in motor area 4 (upper 2/3) of cerebr. cortex.
 - Course: axons descend in Corona radiata then in
 - Genu & ant. 2/3 of post limb of int. capsule →
 - Basis pedunculi of the midbrain (intermediate part) →
 - Basis pontis " " pons. Fibres are separated by t.v. pontine fibres.
 - pyramid in upper medulla. In the lower part of closed medulla, 85% of the fibres cross to the opposite side → motor decussation
 - In the sp. cord the crossed pyramidal tract is present in the lat. column of the white matter in all levels while the direct pyramidal is present in the ant. column of white matter in cervical & upper thoracic.
 - Termination: In AHCs of the opposite side. Some end on the same side. The direct Δ gradually crosses to the opposite side. few fibres end on the same side.
 - Function: Control voluntary movement. ↑↑ tone & reflexes in muscles (Facilitatory to fine & skilled movement)

2. Corticobulbar tracts:

Fibres arise from cerebral cortex & terminate on motor nuclei of cranial nerves in the brain stem:

a. Medial Cortico-bulbar:

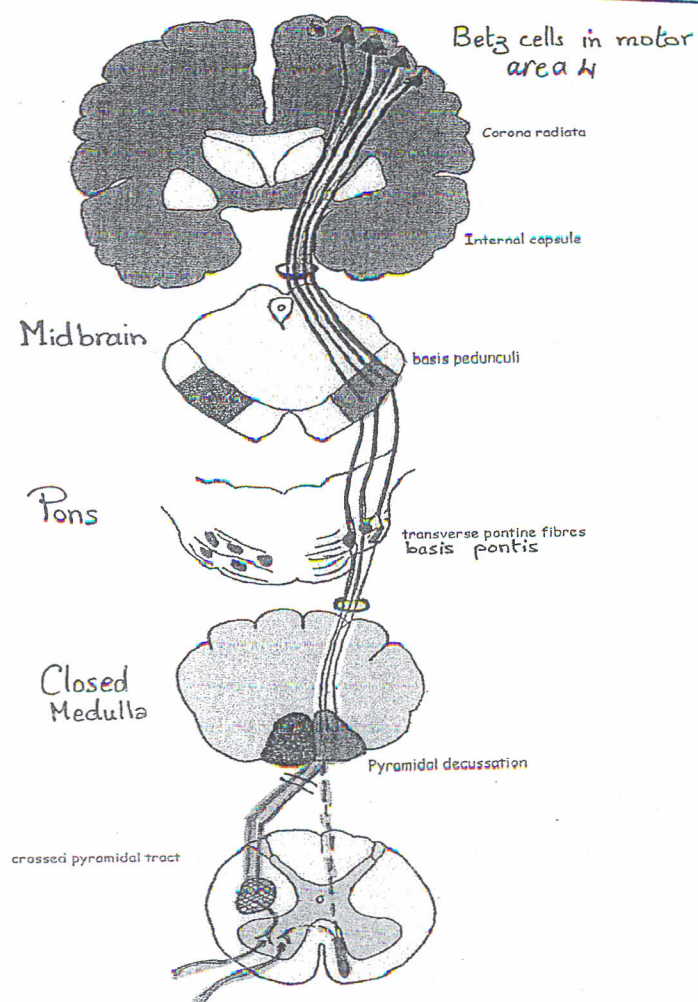
- Origin: motor area 8 in cerebral cortex.
- Course: The axons descend in corona radiata then in Genu of int. capsule
 - In the midbrain they are present in the basis pedunculi close to middle line
- Termination: motor nuclei of cranial nerves 3, 4 & 6 of both sides.

b. Lat. Cortico-bulbar:

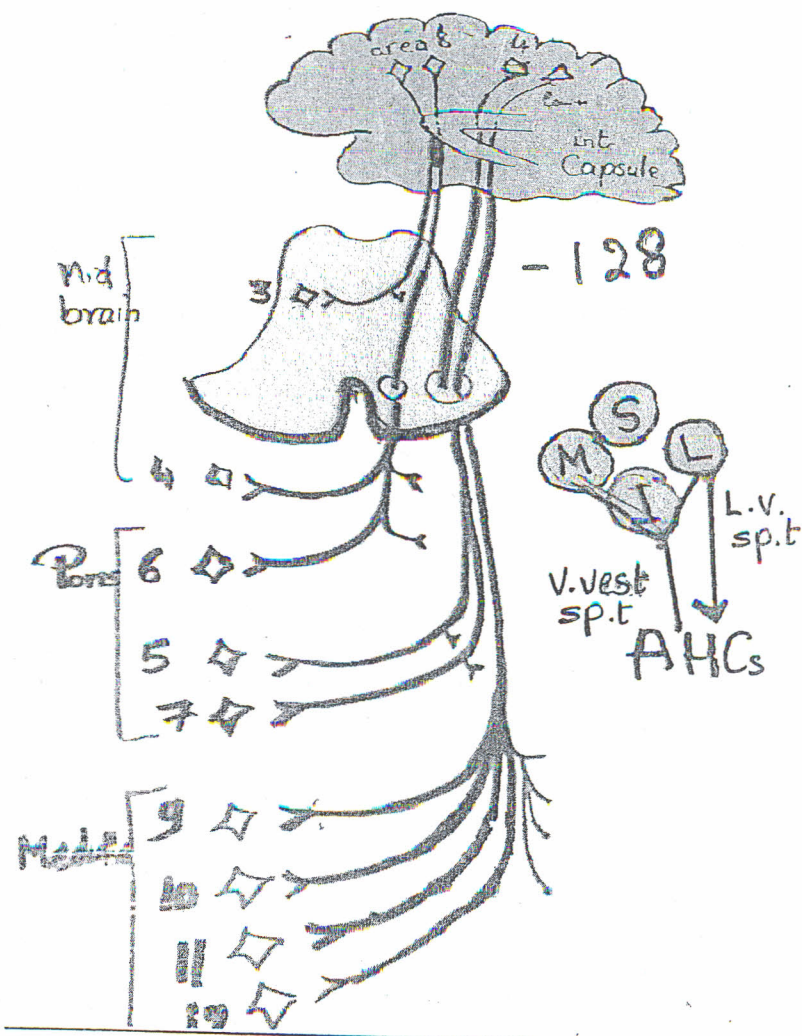
- Origin: motor area 4 (lower 1/3) in cerebral cortex.
- Course: Axons descend in the corona radiata then in the Genu of int. capsule
 - In the midbrain, they pass in the basis pedunculi lat. to corticospinal t.
- Termination: motor nuclei of cranial nerves 5, 7, 9, 10, 11 & 12 on both sides except:
 - the part of 12 that → protrudes the tongue.
 - " " " 7 → innervates the ms of the lower face.

They receive contralateral innervation.

Cortico-spinal t.



Cortico-bulbar



- Extrapyramidal
- = Descending motor tracts w do not pass through the pyramids. 2 group
- (1) Tracts that arise from cerebral cortex & end in the brain stem.
- (2) " " " " Brain stem & " " AHCs of spinal cord.

Extrapyramidal tracts of the spinal cord

Single tracts	Paired tracts
• Rubro-spinal.	• Lat. & vent tectospinal
• Olivo. " "	• " " reticulo " "
• Sulco-marginal.	• " " vestibulo sp.

tract	Origin	type	termination	Function
Sulcomarginal	Continuation of the med. long. bundle		AHCs [All levels]	Associative
Rubro-spinal	Red N. in (midbrain)	Crossed in (vent. tegmental #)	AHCs, (cervical & thoracic)	Inhibitory
Olivo-spinal	Inf. Olivary N.	direct	AHCs (cervical)	Facilitatory
lat. tecto-spinal	Sup. colliculus	Crossed in (dorsal tegmental #)	AHCs (cervical)	Inhibitory
Vent " "	(tectum of midbrain)		" (cervical, thoracic)	"
lat. Vestibulo-sp.	lat. vestibular N.	direct	AHCs (all levels)	Facilitatory
Vent " "	lat., med. & inf. vestibular nuclei	direct	AHCs (cervical)	"
lat. reticulo-sp.	Reticular Formation in Brain stem	- mainly crossed.	AHCs (All levels)	Inhibitory
Vent " "		- " direct.		Facilitatory

∴ 3 tracts rubrosp. } arise from midbrain & crossed
lat. & vent.
tectosp.

3 tracts - Olivo sp. } " " pons & medulla & direct.
lat. & vent.
vest. sp.

3 tracts Sulcomarginal + L. & V. reti. sp. from brain stem as a whole

Med. longitudinal Bundle

-11-

Def.: associative bundle formed of ascending & descending myelinated nerve fibres.

Site: In the brain stem (near the middle line). Its continuation in the spinal cord is: ventral vestibulospinal tract + sulcomarginal tract.

Connections & functions:

(1) Vestibular connections

a. Vestibulo-ocular:

- Connects vestibular nuclei & nuclei of 3, 4 & 6.

F. Coordinates eye movement & head movement.

b. Vestibulo-spinal:

- Connects vestibular nuclei [lat., med. & inf.] & AHCs [V. vest. sp. t.]

F. Coordinates head movement & neck & trunk movement.

(2) Auditory Connections

- Connects Sup. olive + nucleus of trapezoid body + nucleus of lat. lemniscus & nuclei of 3, 4, 6, 7, 11 & 12.

F. Coordinates movement of eye, face, neck & tongue in relation to sound.

(3) Cranial nerves Connections

- Connects nuclei of 3, 4 & 6 of both sides for conjugate eye movement.

- Connects " " 7, 11 & 12 so lips, larynx & tongue work together during speech.

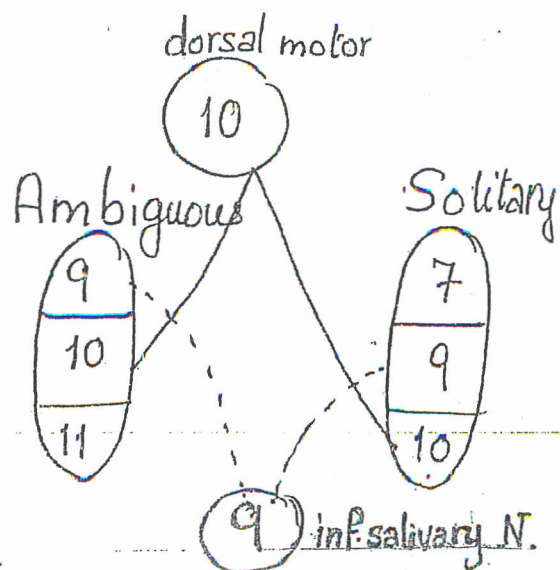
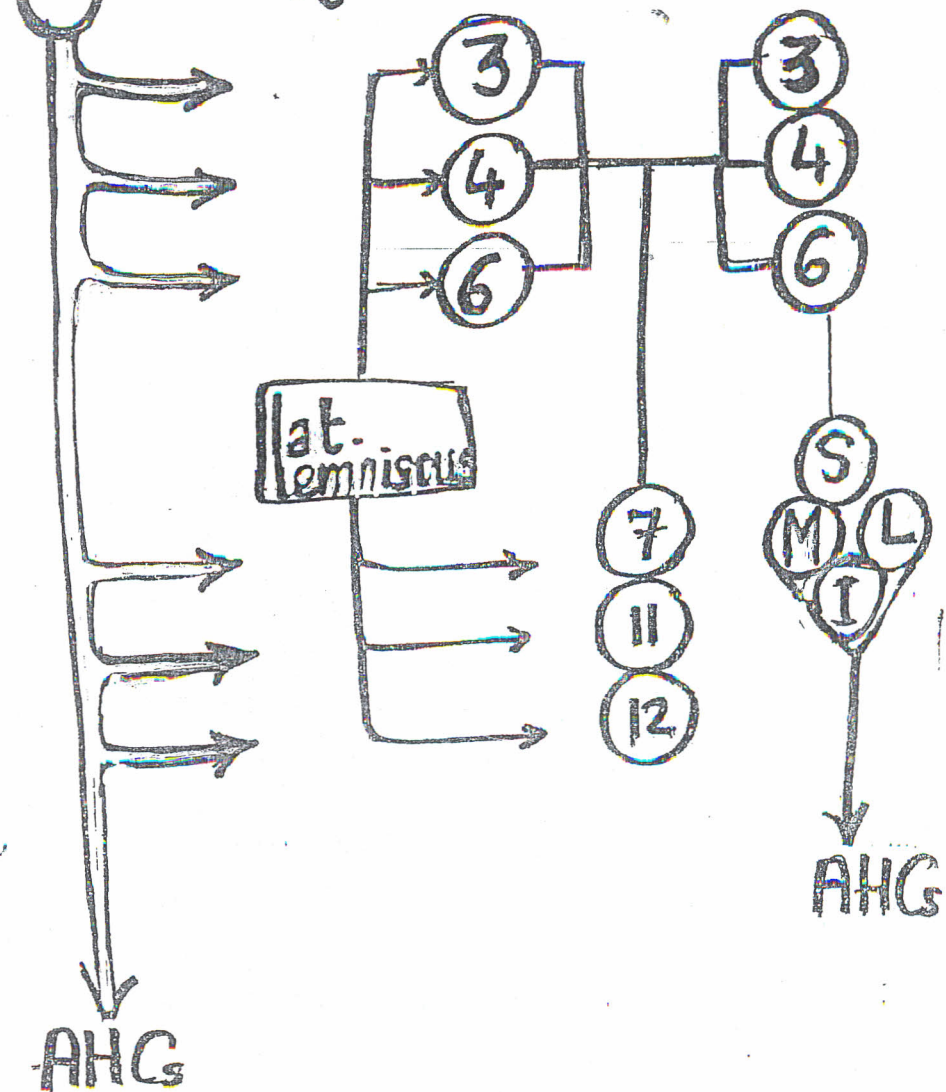
(4) Extrapyramidal Connections

- Connects extrapyramidal nuclei → Interstitial nucleus of Cajal
& → post. commissural nucleus
& motor cranial nuclei & AHCs of sp. cord.

F. control movements of head, neck & trunk.

MLB

Post. commissural N.
N. of Cajal



Visual Pathway

Receptors: rods & cones in retina.

1st Order neurons: Rod & cone cells in outer nuclear layer.

2nd " " : Bipolar nerve cells in inner " " .

3rd " " : Ganglion cells in ganglion cell layer.

Axons of the ganglion cells form the optic nerve.

The nasal fibres cross to the opposite side forming optic chiasma.

The optic tract: contains temporal fibres of the same side & nasal fibres from the opposite side. Some fibres relay in the Sup. colliculus [visual reflexes]. Most of fibres relay in the lat. geniculate body. Their axons ascend in the Optic radiation to the visual area in cereb. cortex (area 17).

Deep Origin of cranial Nerves in Medulla

Hypoglossal Nerve (12): motor nucleus in floor of 4th ventricle.

Accessory Nerve (11):
 → lower part of nucleus ambiguus.
 → AHCs of upper 5 or 6 cervical segments.

Vagus Nerve (10)
 → middle part of nucleus ambiguus.
 → lower part of solitary nucleus.
 → Dorsal motor nucleus.

Glossopharyngeal Nerve (9)
 → upper part of nucleus ambiguus.
 → middle " " solitary nucleus.
 → inf. salivary nucleus.

Connection bet. Gracile & Cuneate nuclei & Cerebellum:

Ext. arcuate fibres:

. Post. ext. arcuate fibres: enter ICP directly to cerebellum.

. Ant. " " " : cross to the opposite side, enter the arcuate nucleus then ICP → cerebellum.

Auditory Pathway

Receptors: Inner & Outer hair cells in Organ of Corti in cochlea.

1st Order Neurons:

= Bipolar nerve cells in spiral ganglia. Their axons form the cochlear nerve which enters the lower level of pons to end in:

2nd Order Neurons:

= Cells of dorsal & vent. cochlear nuclei: Their axons form the trapezoid body then cross to the opposite side & ascend as the lat. lemniscus. Some axons ascend in the lat. lemniscus of the same side.

Axons of the vent. cochlear nucleus relay in: sup. olive or nuclei of trapezoid body or lat. lemniscus.

Fibres of the lat. lemniscus relay in 2 sites
 inf. colliculus
 Med. Geniculate body

Final Order Neurons:

= Cells of the Med. geniculate body. Their axons pass in the auditory radiation to the auditory area in the temporal gyrus area 41 in Cerebral Cortex.

(N.B.) each lat. lemniscus carry hearing from both ears.
 " MGB & each auditory area receives hearing from both ears.

Lat. Lemniscus:

Origin: dorsal & vent. cochlear nuclei in inf. pons.

Course: Axons cross to opposite side → trapezoid body then lat. lemniscus

Terminate in: inf. colliculus & MGB.

Functⁿ: carry hearing from both ears but mainly from opposite side

∴ Brain lemnisci = 4

1. Med. lemniscus. 2. Spinal lemniscus.
3. lat. " 4. Trigeminal "

Vestibular Pathway

-14-

The vestibular nerve maintains equilibrium by coordinating reflexes of eye, neck & body according to position & movement of Head.

Receptors : (5)

• Macula of utricle • macula of saccule • Crista ampularis (3)

• 1st Order neurons = bipolar n. cells in vestibular ganglia.

Their axons end in 5 places : Sup., inf, lat. & med. vestibular nuclei (2nd Order N) + direct fibres to the cerebellum = direct vest. cerebellar

Vestibular nuclei Connections : give 5 tracts :

1- Vestibulo ocular Connections :

Fibres from vest. nuclei pass in the M.L.B. to be connected to nuclei of III, IV & VI (eye movement) & body

F. Correlates eye movement & head movement. (make eye fixed on stationary point during head & body movement)

2- Vestibulo spinal Connections :

lat. vestibulo sp. t. : connects lat. vest. N. & AHCs.

Vent " " " " lat. med & inf. vest. nuclei & AHCs.

F. ↑↑ the tone of extensors of Leg. to support the body against gravity.

3- Vestibulo-bulbar Connections :

Fibres from the lat. vest. nucleus pass through MLB to reach the accessory N.

F. : ↑↑ the tone of extensors of the neck to support the head against gravity

4- Vestibulo-reticular Connection :

Fibres from the vest. nuclei pass through the MLB to reach the reticular formation of mid brain. F. stimulates Vomiting centre.

5- Vestibulo-cerebellar Connections :

Fibres from the sup. vest. N pass to the cerebellum [indirect vest. cerebellar]

Function : direct & indirect fs relay in the flocculonodular lobe → dentate Nucleus → thalamus → cerebral cortex [area 4, 6 & 8].

∴ Cerebellum Can influence the activity of the pyramidal tract.

Deep Origin of cranial nerves in Pons

Vestibulo-cochlear Nerve [VIII]

- Vestibular part: origin: bipolar n. cells in the vestib. ganglion & end in 4 vestibular nuclei (sup, inf., lat. & med) in pontomedullary junction.
- Cochlear part: origin: bipolar n. cells in the spiral gangl. & end in dorsal & vent. cochlear nuclei in inf. pons.

Facial Nerve VII: has 3 nuclei $\left\{ \begin{array}{l} \text{motor N (in inf. pons)} \\ \text{upper part of solitary N (sensory)} \\ \text{sup. salivary N (parasymp) in R.F.} \end{array} \right.$

Abducent Nerve VI Abducent motor nucleus in inf. pons.

Trigeminal Nerve V: 4 nuclei

- mesencephalic Nucleus: in sup. pons + midbrain. Receives proprioception from face
- Motor: in middle pons: motor to ms. of mastication.
- Main sensory " " : receives crude touch from the face.
- Spinal Nucleus: in inf. pons & medulla: receives pain & temp. from the face.

N.B. definitions:

- nucleus = Group of n. cells in CNS.
- tract = group of n. fibres " " have same origin, terminatⁿ & funct
- lemniscus:

A bundle of sensory fibres in the brain stem. It terminates on specific nuclei in the diencephalon.

The meninges

Pia matter: (tender mother)

- A single layer of modified fibroblast that overlap each other. Highly vascular
- Covers the surface of brain & sp. cord.

Arachnoid matter: (network of threads made by spider)

- 2 types of cells $\left\{ \begin{array}{l} \text{border cells: joined by tight junctions & \text{form the roof.} \\ \text{trabecular cells: hold up the roof like pillars.} \end{array} \right.$
- Separated from pia matter by subarachnoid space w contains $\left\{ \begin{array}{l} \text{CSF. \&} \\ \text{bl. vs.} \end{array} \right.$
- Together e' pia matter $\rightarrow$ a compound memb. called pia-arachnoid or leptomeninges.

Dura matter: (tough mother)

- 2 fibrous layers $\left\{ \begin{array}{l} \text{Outer thick separated at sites of venous sinuses.} \\ \text{inner thin} \end{array} \right.$

Cerebellar Connections

• Sup. Cerebellar peduncle : SCP

Afferent:

1. Vent. sp. cerebellar tract.
2. Tecto. cerebellar "

efferent:

1. Cerebello-rubro sp. t.
2. Cerebello-thalamocortical.

• Middle Cerebellar peduncle : MCP

Afferent

1. Cerebro ponto cerebellar.
2. Cerebello " " (from the other side)

efferent

Cerebello ponto cerebellar. (to the other side)

• Inf. Cerebellar peduncle : ICP

Afferent:

1. Dorsal sp. cerebellar tract.
2. Ext. arcuate fs.
3. Olivo cerebellar t.
4. Vestibulo " "
5. Reticulo " "

efferent

1. Cerebello-olivary t.
2. " vestibular t.
3. " reticular t.

Cerebrum

The cerebral cortex = 6 layers :

1. Molecular layer = parallel fs from next layers + Horizontal cells of Cajal.
2. Outer granular L = small pyramidal cells + stellate nerve cells.
3. Out. pyramidal L = med. sized ^(8 μm) pyramidal cells [40-50 μm].
4. Inner granular L = stellate nerve cells.
5. Inn. pyramidal L = large pyramidal cells [100 μm] = Betz cells.
6. polymorphic cell L. = nerve cells of diff. types & shapes.

Brain Barriers

1] Blood brain barrier :

def : the barrier bet. blood & nerve cells of the brain : formed of :

- tight junctions bet. non-fenestrated endothelial cells of the capillaries
- Thick continuous basement memb. of the capillaries.
- Vascular end feet of astrocytes implanted on " "

Function : 1- prevent harmful substances from reaching nerve cells.
2- allows passage of nutrition & precursors of neurotransmitters by facilitated diffusion & active transport.

2] Blood CSF barrier :

def. : the barrier w separates blood from CSF. formed of :

- endothelium of choroid capillaries.
- Basement memb of " "
- " " of ependymal cells
- Tight junctions bet. " "

Function : 1- Protection 2. Maintenance & constancy of CSF.
3. Selection of substances to pass from bl. to CSF.

3] Arachnoid Barrier :

- Def : the barrier bet. extracerebral capillaries & subarachnoid space.
- formed of : arachnoid cells joined by tight junctions & desmosomes.
- Functions : prevent substances leaving extracerebral capillaries from reaching subarachnoid space, nerve cells of brain & brain ventricles.

In fetus & newborn : B.B.B. is not fully developed so, toxic subs. e.g. bilirubin can enter the CNS → yellowing of the brain.

- Direct trauma, inflammation or toxin → breakdown the BBB allowing large molecules to enter the CNS.
- On administration of penicillin, only small amount can enter the CN. (toxic in high concⁿ.)
- In meningitis, the meninges become more permeable at the site of inflammation allowing sufficient antibiotic to reach the infection
- In brain tumors, bl. vs frequently have no BBB.
- In the hypothalamus, the bl. caps are fenestrated & no BBB → ptns. & small molecules may pass to CNS allowing modification of metabolic activity of this area of the brain → protecting the nervous tissue as a whole.

Upper Motor Neuron = n. cells in cerebr. cortex or subcortical level
& end on AHCs (or) motor nuclei of cranial nerves

Lower Motor Neuron = AHCs or motor nuclei of cranial nerves
give axons that end on muscles.

General rules for sensory Pathways

1st Order Neuron = Cells of spinal ganglia (same side).

3rd " " = " " PLVN of thalamus (opposite side).

2nd " " For proprioception & fine touch in medulla (same side)
" " " " pain & temp + crude (simple) in sp. cord (" ")

Axons of 2nd Order neuron cross in:

- sp. cord (pain, temp. & crude touch).
- medulla (proprioception & fine touch).